THE DEEP ULTRA-VIOLET FREE ELECTRON LASER (DUV-FEL)

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It is certainly no secret that *the* activity at the source development laboratory has become the Deep Ultra-Violet Free Electron Laser (DUV-FEL). Adopted as one of four BNL initiatives, the DUV-FEL has been the focus of considerable activity in the last year. The objective of the program is to provide a sound technological foundation for sources and science that will lead to the next generation of synchrotron radiation based research. BNL shares the view with many other laboratories that these machines will be Free Electron Lasers, and that getting to short wavelengths will require single pass configurations.

The BNL effort has, from its inception, held the view that to be useful experimental tools these machines must wed the best aspects of solid state lasers with accelerator technology. The source must have the characteristics of stability and optical quality people have come to expect in laser technology, while operating at wavelengths that are only readily accessible using accelerator based amplifiers. The High Gain Harmonic Generation (HGHG) approach proposed by Yu *et al.* is the central concept for the DUV-FEL.

A photon beam from a solid state laser is made to couple with an electron beam in a short "energy

Photo A: (from left to right) Richard Heese, Erik Johnson and Bill Graves reveal the secret location of the DUV-FEL!

modulation" undulator. This introduces an energy modulation in the electron bunch that is converted to a spatial modulation in a magnetic dispersion section. The electron beam thus has a micro-bunching imposed on it which has characteristics related to the seed laser. A second longer "amplification" undulator is used to produce coherent radiation at either the fundamental (same wavelength as the laser and microbunching) or a higher harmonic (shorter wavelength than the seed laser). In the HGHG scheme, the stability properties of the laser (central wavelength, bandwidth, pulse length) are translated into the FEL output, while the accelerator effectively acts as an (optical) dispersion-free harmonic generator and amplifier. In principle the scheme provides exactly what we desire in a fourth generation source. In practice, this all has to be proved experimentally, which is one of the main goals of the DUV-FEL project.

To make this project possible, several years ago the NSLS collected together an assortment of recovered equipment that could be used to assemble the experiment. The Source Development Laboratory (building 729) houses the linac from the x-ray lithography project, and a long undulator (NISUS) originally built for directed energy weapons research. For our DUV-FEL project, the linac must become a high brightness machine with a photocathode gun as an electron source. To operate in HGHG mode the DUV-FEL needs a flexible laser system not only to drive the gun, but to provide the seed beam for the FEL. The demands on the laser are sufficiently stringent that it was built specifically for this application.

The transformation of the linac from a ring injector to an FEL driver has been guided during the last year by Richard Heese and Bill Graves, and accomplished by a great deal of hard work from people all over the NSLS. This activity includes some fairly basic infrastructure as well as the novel technical developments one might anticipate in such an endeavor. For example, precise temperature control of the linac is required. In fact it runs at 45°C, while accessory cooling for power supplies must be provided. The design of this system was performed by the NSLS utilities group and installation was accomplished with Plant Engineering personnel (see Photo B).

To get its "Cinderella" treatment in moving from ring injector to FEL driver, the linac had to be totally reconfigured. This included the installation of a photocathode gun by Xijie Wang based on his work at the Accelerator Test Facility. Another major improvement is the addition of a pulse compression chicane system developed by Bill Graves to increase the peak current of the electron beam, which will significantly improve the FEL performance. This involves an enormous amount

Photo B: Some of the people responsible for the installation and operation of the process water system for the DUV-FEL. Clockwise from left, Mike Ponticiello and John Fogus (Plant Engineering), Mike Schwartz, Ron Beauman, and Lenny Santangelo (NSLS Utilities).

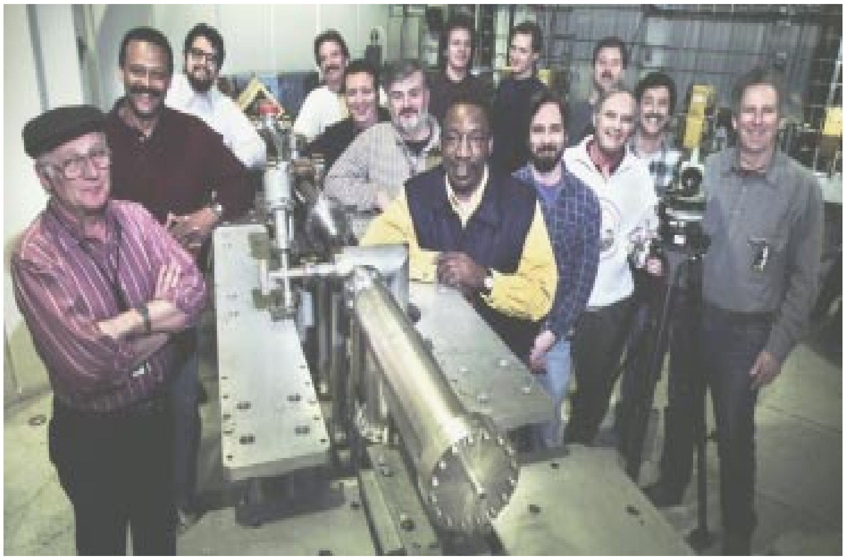


Photo C: Part of the crew responsible for the mechanical design and installation of the DUV-FEL linac system. From front on the left of the beam dump, Mike Radulescu, Mal Tardd, and John Skaritka. Working from back to front on the right side of the beam dump, Pete DeToll, Chris Stelmach, Bob Scheuerer and Skip Thomas. Working left to right in front, Jeff Aspenleiter, Dick Wiseman (hand on transit), Mike Caruso and Bill Bambina. In back (left to right) Sal Pjerov, Peter Gross and Roger Hubbard.

of mechanical work in design, fabrication and installation. Only a handful of the people who have worked on the machine thus far were available for the picture given here (Photo C).

A key element of our project is the integration of laser science into the FEL. Lou DiMauro from the BNL Chemistry Department has been leading this effort for the DUV-FEL. The laser we selected is a Titanium Sapphire system with a regenerative amplifier. It is a chirped pulse amplification system that produces adequate power for running the photocathode gun and for seeding the FEL. The chirped pulse can in principle be used to produce a chirped pulse amplified (CPA) FEL. Simulations show that pulses the order of 10 femtoseconds can be generated with pulse energies of nearly a millijoule in the deep ultra-violet. Apart from the technological development of the laser system, extensions of laser based science now practiced in the laboratory need to work their way into the machine and the science it is intended to serve. This has been part of our project philosophy from the start, and we expect it to be important in making FEL's genuinely useful for research. Part of the team working with Lou on the laser systems is shown in Photo D.

Of course once you have brought the components together, you have to connect them, condition them, and make them work. Reconfiguring the linac has been as much an electronics and control task as a mechanical task. During the past year, the linac computer control system was entirely revamped to use the same type of software as

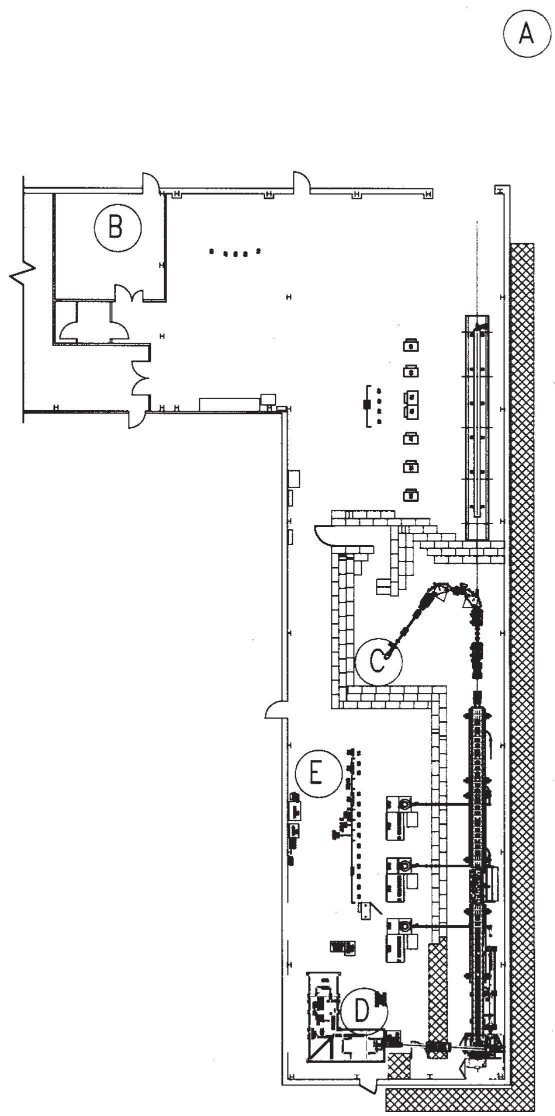
PhotoD: Part of the laser development group in the laser lab (clockwise from left) Brian Sheehy (Chemistry), Todd Clatterbuck (SUNY SB), Paul Montanez (NSLS), and on the wallpaper here for the first time (virtual) Lou DiMauro (Chemistry).

Photo E: Some of the people who make the linac go; Clockwise from left Jim Garrison, Jeff Rothman, Richard Heese, Bill Graves, Charles Nielson, Kate Feng-Berman and Boyzie Singh.

the NSLS machines. The electrical systems have been brought up to current codes, and extensive modifications to the low level RF drive system and interlocks were performed to enhance their reliability. Finding and fixing each bug as it crops up is a demanding task that requires perseverance and experience. Fortunately the NSLS has broad experience in this area as exemplified by the people in Photo E. At the time of writing, the system has been powered up and high power RF conditioning of the accelerating sections has been started.

During the next year, the plans include bringing the linac into full operation, and preparing our undulator for conducting the first FEL experiments with the DUV-FEL. Initially we will start running as a self amplified spontaneous emission (SASE) FEL in the visible. In this mode, a high quality electron beam passes through the undulator and starts up from noise. From an experimenter's viewpoint, what you get is essentially loud noise at the end, but it is a stringent test of the electron beam quality and is less complex to operate than a seeded beam FEL. As technological achievements allow, we will move as rapidly as possible to seeded beam operation and to shorter wavelengths.

The development of Fourth Generation Sources is becoming an important priority for the DOE. Many of the proposed experiments nation wide, including parts of the DUV-FEL, are being conducted in collaboration with scientists from universities and other national laboratories. The DUV-FEL project has progressed to a state of development where it will be the focus of major activity in this area over the next several years, and we hope, in establishing the basis for future source technology and science. ■



Map of the SDL, marked with the locations of photos taken. (A through E).